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**COST INFORMATION REQUIREMENTS FOR MANAGING AIRCRAFT
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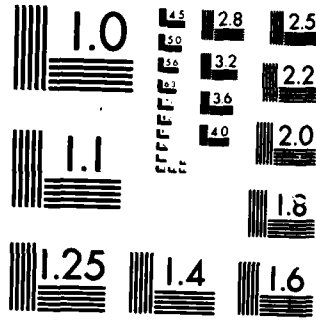
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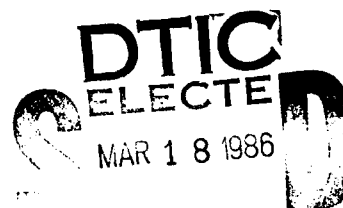
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NAVAL POSTGRADUATE SCHOOL

Monterey, California



THESIS

COST INFORMATION REQUIREMENTS
FOR MANAGING AIRCRAFT REWORK

by

David Phillip Faust
and
John Wayne Highsmith

December 1985

Thesis Advisors:

John W. Creighton
Casimir E. Lawler

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<p>Managing the diverse aspects of a Naval Air Rework Facility is a complex and demanding task. This report provides fresh input into two of the areas that are of concern to NARF management on a daily basis.</p> <p>First is the management of cost data to provide meaningful information for managers at all levels of the organization. Included is a brief explanation of the economic rationalization that supports the Life Cycle Cost concept. A discussion of the types of financial information needed by managers and deficiencies in the NIF accounting system follows.</p> <p>The next section centers on the basis behind the Reliability Centered Maintenance concept and how the deficiencies in the information collection system at NARF Alameda fail to support the demands of this concept.</p>					
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Cost Information Requirements for Managing Aircraft Rework

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ABSTRACT

Managing the diverse aspects of a Naval Air Rework Facility is a complex and demanding task. This ^{has} report provides fresh input into two of the areas that are of concern to NARF management on a daily basis.

First is the management of cost data to provide meaningful information for managers at all levels of the organization. Included is a brief explanation of the economic rationalization that supports the Life Cycle Cost concept. A discussion of the types of financial information needed by managers and deficiencies in the NIF accounting system follows.

The next section centers on the basis behind the Reliability Centered Maintenance concept and how the deficiencies in the information collection system at NARF Alameda fail to support the demands of this concept.

Recommendations are provided to alleviate both short and long run deficiencies.

Keywords: 5-3 aircraft

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LIST OF ACRONYMS

CFA	Cognizant Field Activity
DMDS	Depot Maintenance Data System
DOD	Department of Defense
FMEA	Failure Modes and Effects Analysis
FRSC	Fleet Readiness Support Conference
JON	Job Order Number
LCC	Life Cycle Cost
NALC	Naval Aviation Logistic Center
NAMP	Naval Aviation Maintenance Program
NARF	Naval Air Rework Facility
NAVAIR	Naval Air Systems Command
NIF	Naval Industrial Fund
OSP	Operational Service Period
RCM	Reliability Centered Maintenance
SDLM	Standard Depot Level Maintenance
SSI	Structurally Significant Item

I. INTRODUCTION

Within a socio-economic environment characterized by public demand for efficiency and economy in government, tight management of dollar and material resources has become absolutely necessary for Department of Defense activities. As DOD managers at all levels have faced shrinking budgets and level or increasing workloads, austerity measures and belt tightening exercises have been required. Because of these trends, managers have been forced to examine closely every facet of their organizations which competes for a part of the monetary resource in an effort to eliminate inefficiencies and ensure that finite dollars are expended exactly where most needed.

As the Cognizant Field Activity and Designated Overhaul Point for the S-3 aircraft and related equipment, NARF Alameda has been subjected to such budget tightening measures in recent years. These measures have been imposed by other command echelons in spite of upward trending rework costs and unanticipated failure/degradation modes discovered on inducted aircraft. Increasing workloads have not been met with commensurate increases in resources. In addition to simple budget reductions, the Naval Air Systems Command (NAVAIR) has recently considered a lengthened operating service period (OSP) for the S-3. The consensus among NARF

managers is almost unanimously against a longer OSP. The belief being that the goals of fleet S-3 readiness and safety would not be served by such a measure. A NARF attempt to propose a reduction in OSP length, however, was only a qualified success: The proposal failed to achieve a shorter OSP, although it did postpone the length increase being contemplated.

NARF Alameda managers perceive a need for changes in NARF operations and functions that will improve internal management efforts and better enable the NARF to respond to external pressures for changes to rework programs and budget reduction. Specifically, the needs for change appear mainly around four areas:

1. Improved management cost information and use.
2. Full integration and use of Reliability Centered Maintenance (RCM) techniques.
3. Improved methods for gathering, interpreting and managing aircraft failure data.
4. Development of improved management perspectives regarding S-3 rework program costs and OSP issues.

These areas are the center of focus for this report and form its objectives, which are:

1. Provide management perspective through a brief review of the program Life Cycle Cost (LCC) concept and how NARF rework costs impact LCC.
2. Determine which specific cost information types seem most useful for internal management, and show how this information might be gathered at least cost to NARF.

3. Review the evolution of RCM techniques in order to demonstrate their importance to rework package content. Apply RCM logic to the OSP issues presented by NARF so as to provide insight about the constitution of a defensible OSP proposal.
4. Provide action priorities for NARF managers in order to enable a systematic approach to the large and relatively unstructured problems of improving the management information system.

Chapter II addresses cost areas, Chapter III OSP issues and RCM techniques. Chapter IV presents conclusions and specific recommendations for action.

II. COST INFORMATION FOR MANAGEMENT

Managers of the NARF rework effort must meet schedule deadlines while operating within budget limits and ensuring that standards of quality, safety and readiness are not compromised. With these objectives in mind, they routinely make strategic and global tradeoff decisions so that goals are accomplished while constraints are observed. This chapter addresses ideas concerning the impacts of rework costs upon the Life Cycle Cost (LCC) of an aircraft program, and the relevant cost information needs of the managers who make cost tradeoff decisions.

The costs that are associated with the Standard Depot Level Maintenance (SDLM) of a major weapon system such as the S-3 are one subset of all the costs that make up the total LCC of that weapon system. Some other cost areas which contribute to LCC are manpower and training cost, operations and maintenance cost, configuration update cost and retirement cost. The latest Navy Program Manager's Guide states that program managers must consider "... life cycle cost such that affordability is put on an equal basis with system performance, schedule and logistics supportability." [Ref. 1: pp. 1-5] In recent years, increased emphasis and effort have been devoted to the

understanding and management of the LCC of major weapon systems, and with good reason. Experience with past projects demonstrates that concentration only upon the management of dollar totals within each subset of the LCC of a major system without regard to the functional relationship that exists between these cost areas is a serious and often expensive error.

As an example, impact on operations and maintenance costs of a decision, made early in the procurement process, to minimize design and production costs by eliminating fleet maintainability enhancement features such as access doors. Such a decision saves money in the design and production stages, but this savings is wholly offset, depending on the planned life of the system, by the additional operation and maintenance costs incurred because such maintainability enhancement features are not present. This scenario serves to illustrate some important points. First, managers must take a "macro" view and concern themselves with the total LCC of a weapon system in order to get the most "bang for the buck." This does not, however, imply paying less attention to the management of all of the component costs which make up the LCC. Indeed, the management of these subset costs is just the vehicle through which LCC is managed. Also, control of LCC depends not only upon the algebraic sum of all subset costs--it depends as well upon

the relationships between these subsets and how each affects others. Understanding these functional relationships between cost subsets is as important to LCC management as is cost control within subsets.

S-3 rework costs comprise a significant component of the operation and maintenance costs for this weapon system and therefore have a definite impact upon the S-3 LCC. Management of these costs is crucial as a result. To gain insight about this management effort, an overview of aggregate SDLM costs as they seem to relate to LCC is presented. An examination of relevant cost information types follows.

Some important functional relationships seem to exist between the S-3 program's LCC and various aspects of the SDLM process at NARF Alameda. First, with all other factors constant, one would expect S-3 LCC to vary as a dependent variable with Operational Service Period (OSP) length in a manner similar to that depicted in Figure 1. [NOTE: The axes for this and following figures are ungraduated since the primary concern here is the relationship.] The reasoning underlying this relationship is fairly straightforward. In Figure 1, SDLM frequency (the independent variable), is based upon the length of the OSP between scheduled rework points. In other words, the number of times SDLM occurs must increase as the time periods

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Note: Point B represents the point where
SDLM frequency is at its optimum.

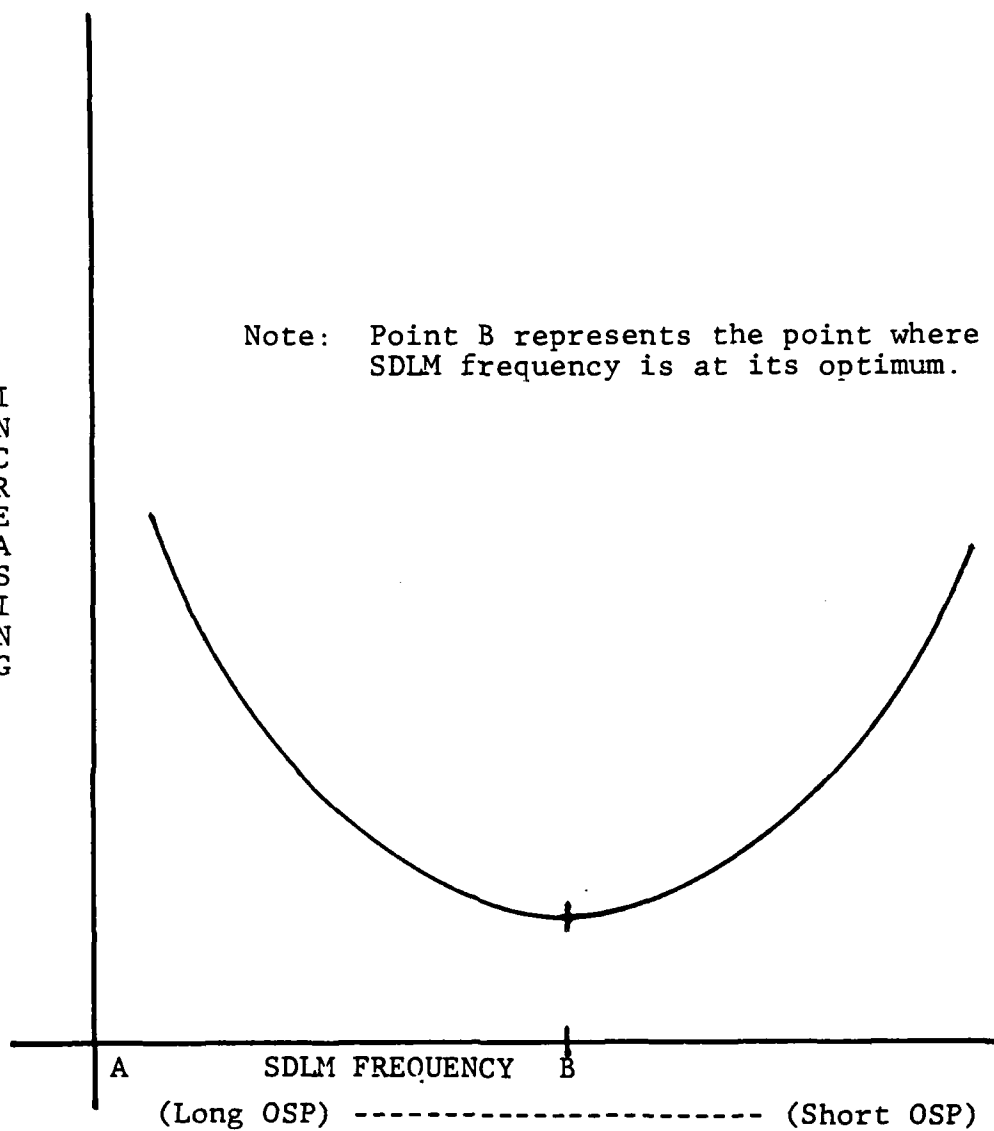


Figure 1. Life Cycle Cost as a Function of
SDLM Frequency

between SDLM points are shortened. Keep in mind that the LCC in Figure 1 includes intangibles such as the cost of unchecked aircraft deterioration, the cost of lower operational readiness, the cost of decreased safety margins, and so on. Indeed, these intangibles cause the characteristic shape of the curve. At point A in Figure 1 there are no SDLM's and the OSP length is equal to the life of the airplane. In this situation, LCC is high even though SDLM costs are zero, because the intangible costs associated with decreased safety and readiness increase. Additionally, fleet organizational and intermediate maintenance costs increase as the condition of aircraft deteriorates over time, and fleet organizations (O and I levels) take on responsibility for performing the industrial maintenance tasks that NARF's would have performed (total repaint, in-depth structural repair, fabrication, etc.). As one moves from point A towards point B, along the horizontal axis, SDLM frequency increases as OSP length is shortened, and LCC falls towards a minimum at point B. This minimum represents the point at which the optimum number of SDLM cycles occurs: Any fewer and the savings in SDLM costs are more than offset by the rise in tangible and intangible costs just discussed; any more SDLM cycles and savings in tangible/intangible costs are more than offset by the rise in SDLM cost. Proposals for a longer OSP rest upon the assumption that the

aircraft is presently at some point past B on the horizontal axis of Figure 1, and that lower overall costs would result in reducing the number of SDLM cycles (e.g., moving leftward towards B).

A second functional relationship, in which overall S-3 LCC varies dependently with the cost of performing an average SDLM package, can be contemplated when the number of SDLM cycles is held constant, every 72 months for the life of the airplane, for example. A graphic approximation of this function is shown in Figure 2. This simply shows that LCC is expected to increase as the cost of performing SDLM work packages on the aircraft increases. Some important implications underly this seemingly simple relationship. First, if the overall goal for the S-3 program is to provide a set level of effectiveness, measured in terms of fleet readiness, safety and so on, at the lowest possible LCC, then proposals for a longer OSP from higher command echelons make sense. This assumption of an effectiveness goal for the S-3 is based upon the economists' definition of efficiency. Hitch and McKean put it this way: "The use of resources is efficient . . . with a single valuable output or objective (S-3 readiness and safety in this case), where it is impossible to increase the output without increasing the use of . . . one of the most valuable inputs (S-3 budget dollars here)." [Ref. 2: p. 116] To put it simply, if S-3

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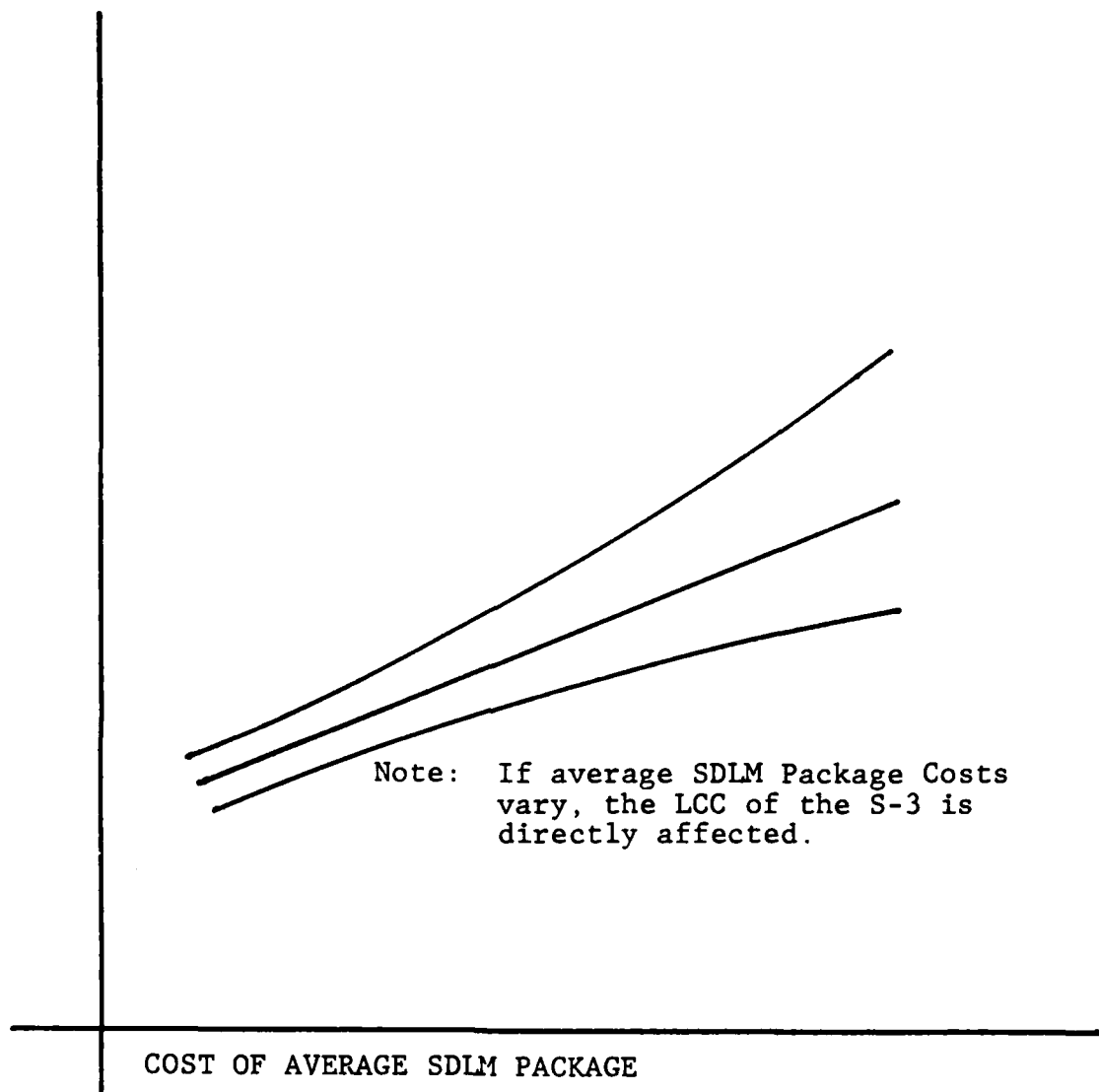


Figure 2. Life Cycle Cost as a Function of SDLM Package Cost

effectiveness goals are being met, then any possibility of cost savings becomes extremely attractive and the search for them likely will continue. Figure 2 also implies that managers should know the general characteristics of SDLM costs, specifically which cost areas may contain slack, and which must be vigorously defended because they are absolutely vital. For example, indirect labor cost allocations are probably less critical than direct material costs.

A more subtle characteristic shown in Figure 2 is that the relationship between LCC and SDLM work package cost is not necessarily linear. In fact, because the function relating these two variables is probably very complex and almost certainly not linear, three curves are shown. Nonlinearity means that a change in SDLM work package cost may increase LCC at an increasing, constant, or decreasing rate. An example of such an impact would be a situation in which a particular component's inspection, removal and replacement maintenance actions have been determined to be required only at six year intervals. If these maintenance actions are removed from organizational requirements and placed in a SDLM work package, the cost of the affected work package increases by just the amount that it costs to do these added maintenance actions. This added SDLM cost could be more than offset by savings realized when fleet

organizational units are no longer required to train for this maintenance task or carry the special tools and fixtures required to perform it. While this example is contrived, the relationship it demonstrates between the cost of performing maintenance as part of a SDLM work package or performing it at some lower level is one that NARF managers must heed. Other cost relationships exist, but the intent here has been to direct them along these lines rather than list all possible variations on the theme.

Other areas of investigation are appropriate at this point, as they regard SDLM cost. The first concerns the types and characteristics of cost information most useful to management. Second is an analysis of the cost information system presently in operation at NARF Alameda with particular attention paid to the information that it does not provide. Third are recommendations for filling information gaps.

When examining the cost information needs of NARF managers, one should distinguish between cost "data," as expressed by raw numbers, and cost information. Information is data that has been processed/scrubbed and, in this sense, is that which contributes to a manager's knowledge, allowing the exercise of judgement in order to draw conclusions and formulate plans of action. Information, as opposed to data, allows the exercise of management control, which Mautz and

Winjum [Ref. 3: pp. 12-14] define this way: "The accountant's concept of accounting control is specific as to source, historically traceable in official documents, and reasonably clear as to scope." The concept of control held by executives is none of these.

- management control integrates with other management responsibilities and with management goals and purposes.
- management control is a broad concept including both positive goal directed activities and error and irregularity measures. It subsumes internal accounting control.
- management control is personnel oriented, directed at facilitating their success in attaining company goals within company policy.

Mautz and Winjum further assert that "Management control actions are positively directed toward the achievement of company goals as well as precautions and defensive measures" [Ibid.: p. 15] Within the context of this report the term "cost information" refers to that processed data which would enable a NARF manager to exercise management control as defined by Mautz and Winjum. The information is not an end in itself, but is important only insofar as it enables managers to:

- Set goals.
- Monitor achievement of those goals.
- Focus on problems or other areas which warrant attention.

- Respond to changes in environment or circumstance while maintaining perspective with respect to goals and progress toward their achievement.

What characteristics should cost information possess in order to truly facilitate the exercise of management control? The first and probably most obvious is timeliness. Information needed to make a decision is useless if it is received after the decision is made, although it still can be useful in the analysis of trends. The requirement for timeliness must usually be met before other characteristics of information become important. Once timeliness is achieved, however, management will need information that is concise, accurate at the time it is called for, and relevant. Where relevancy is concerned, managers need an information system that is flexible enough to respond to their non-standard information requests. One should bear in mind that not all information needs will have the same priority, nor will all need to meet the same standard of accuracy. To ask for information tomorrow when next week would do, or to demand accuracy to the penny when a rough estimation would suffice, burdens the information system and can render it unable to respond to other requests.

With respect to information types, the generic areas which seem most useful are trend information and information of special interest, aberrations, or situations which exhibit abnormal cost behavior. Rather than presume to tell

managers exactly what should be looked at, the intent here is to point to areas that might be useful and to point out what those uses might be. Research for this report included a study indicating that rework costs for S-3's over the last one and one-half years showed a fairly steady increase. In it, the cost data were aggregated. That is, it included all costs that were required to produce a "reworked S-3," such as direct and indirect labor, materials, and so on. This is an example of trend information. The study is nonspecific, in that it uses many sources of cost data to present an overall picture. The overall picture is important in providing insight and calling management attention to possible problem areas, and can be extremely useful when managers want to evaluate organizational performance in terms of goal achievement. Such a broad view is not as effective as an indicator for the root causes of problem areas. The above study does not show, for instance, whether or not indirect material costs played a significant role in the escalation of overall costs of S-3 rework.

In addition to trend information about overall cost performance, management needs specific cost element trend information. Too much information can be worse than too little, especially when its collection requires inordinate amounts of time and effort. What must be decided upon is just which specific cost elements need monitoring. A system

to gather required information about these cost elements, which consumes the least possible amount of organizational energy, can then be designed and implemented.

The other important information type deals with special, abnormal and generally non-recurring situations. Just as specific trend information about an individual cost element complements the overall trend or picture, so does information about special situations and abnormal cost behaviors complement both types of trends to form a comprehensive information picture upon which management judgement can be exercised. Again there is the danger of gathering too much information, with the attendant risk of attempting to "micro-manage" every cost "spike" that occurs. An adaptation of a quality sampling technique could be used to safeguard against this tendency. For example, a range could be established around the average direct labor cost for the last fifteen S-3's to be reworked, and only those future aircraft whose direct labor costs fell outside of this range would be brought to management attention as candidates for further investigation.

At present, the types of information just discussed are not provided to NARF managers on an established basis. Indeed, the lack of an established source for this information is largely the reason for commissioning the study noted above. The cost accounting system from which

the data for that study came is the same system required for the management of the Navy Industrial Fund (NIF) at NARF Alameda. An examination of this accounting system, with respect to the information it can and cannot provide, is now appropriate, and will suggest recommendations for improved cost information gathering methods.

Watts and Henderson [Ref. 4:p. 8] state that Congress, through Public Law 216 and the National Security Act as amended:

" . . . Authorized the Secretary of Defense to require the establishment of working capital funds in the Department of Defense for the purpose of providing working capital for such industrial type, and for such commercial type activities as provide common services within or among the departments and agencies of the Department of Defense, as he may designate, in order to control and account for the cost of programs and work performed."

This was the legal foundation for the establishment of Naval Industrial Fund activities. As Watts and Henderson further show, "Congress intended, by establishing . . . (these) . . . funds, to ensure that the proven business techniques of financial cost accounting and expenditure controls for work performed should be applied at the working levels that performed work or services comparable to certain civilian enterprises." [Ibid.:p. 9] Finally, Watts and Henderson paraphrase existing regulation to show that [Ibid.:p. 10]:

The purposes of the funds . . . are as follows:

- a. To provide more effective means to control costs of goods and services produced, and a more flexible and

effective means to finance, budget and account for such operations.

- b. To develop a greater sense of responsibility and value among customer activities which, within their own fund limitations, will tend to order only what is necessary . . . and to create a complete buyer relationship whereby the customer can criticize cost, quality of work, and delivery speeds of goods or services performed.
- c. To simplify each industrial funded activity's ability to fulfill its responsibilities by separately financing its operations
- d. To achieve performance-type budget and accounting structures wherein costs are related to specific functions or programs and their end uses.
- e. To enable cross-servicing among military departments because of the financial similarities and advantages cited above.

How are these objectives achieved through the NIF accounting system at NARF Alameda? First, the funding that NARF receives with which to carry on its aeronautical rework program is based upon a negotiation process with the Naval Aviation Logistics Center (NALC). These negotiations take place yearly, and quarterly for update, during what are known as Fleet Readiness Support Conferences (FRSC). In preparation for such a conference, NARF staff personnel obtain anticipated workload data based upon depot maintenance/service requirements, aircraft issue requirements, flying hour program requirements for engine and component rework, and utilization to determine rework needs for ground

support equipment and other supporting programs. Using this anticipated workload, staff personnel formulate workload standards for aircraft, engines and components. Then, using these standards, charge rates are derived for direct labor, indirect labor, material and overhead that would enable the NARF to just break even. This break-even philosophy is intended to ensure that the industrial fund, composed of NARF cash and assets, neither expands because of overcharges to customers nor shrinks because of undercharges. These norms and standards are negotiated at the FRSC and adjusted as necessary, and then are used by the NALC to fund the NARF, which charges customers at those rates until they are renegotiated.

The process of charging these rates to customer activities constitutes the portion of the NIF accounting procedure designed to ". . . induce (those) customer activities to order only what is necessary," as addressed by Watts and Henderson. It is based upon the concept of directly associating costs for labor, material and other services to end products and overhead functions, and is described in detail in the Naval Air Rework Facility Cost Control Manual, [Ref. 5: NAVAVNLOGCENINST 03.1/AS.1P WPC-13403]. Briefly, direct association of cost to end items is accomplished by means of Job Order Number (JON). According to the NARF Cost Control Manual [Ref. 6: p. 1-2-1]: "Cost

accumulation is accomplished through job orders coded to basic source documents covering labor, material and other costs." These job orders include basic information concerning the type of work and the identity of the customer authorizing the work. Cost data is accumulated and posted to the job order by multiplying man-hour and material usage data from a shop transactor system by the appropriate labor and material rates. An "acceleration rate" is applied to direct labor figures and others to arrive at the appropriate overhead charges. This description of the operation of the existing accounting system, although brief, will serve as a basis for examination of the information that the system provides as well as those areas where it falls short.

The NIF accounting system at NARF Alameda is effective in that it does precisely what it is designed to do. That is, it ties funding levels for the NARF directly to projected workload, it accumulates costs and associates them with specific end items, and it provides a vehicle for charging customer activities for work performed. These functions serve to make customers value-conscious and ensure that the NIF neither grows or shrinks. The system is generally geared to provide the information that is necessary to service external relationships between NARF and funding activities and between NARF and customer activities. Discussions concerning management information needs that

appeared earlier in this report centered primarily around the information required for internal management, and in this area the NIF accounting system is weak for a number of reasons.

The most important issue is timeliness. As shown above, the NIF accounting system is designed to respond to information needs that occur on a quarterly or yearly cycle. That is, the system provides budget variance data. A budget variance would occur when the standard rates charged for labor, materials, and overhead are either too low or too high, resulting in NIF shrinkage or growth. In order to ensure that costs are associated with end items, JON's for aircraft often must remain active three to five months after rework on the aircraft has been completed. This necessary characteristic of the NIF system results in its inability to meet, on a regular basis, the need for timely internal management information. The system is not designed to provide routine and timely bi-weekly or monthly trend and special information to middle managers about costs.

Another issue is accuracy. Research indicates that some error is introduced into information provided by the NIF system because work completions cannot always be transacted immediately. The cause of this problem can be traced almost directly to the high level of personnel turnover within the workcenters. As a consequence, workcenter supervisors must

make transactions as time permits. Managers who intend to use this information, then, must realize that it may be somewhat distorted. The following discussions concern information provided by the Depot Maintenance Data System (DMDS) and how it meets information needs not met by the NIF system. It is important to remember that DMDS depends upon the same net of transactors used by the NIF system as a primary data source, and is therefore subject to the same distortion. If managers remain aware of this fact, DMDS can be a powerful management tool.

The DMD System is designed to collect and incorporate depot repair, replacement and consumption data into the 3-M and NALC data bases. It responds to a recognized need for depot data as well as intermediate and organizational level data when making decisions concerning stock levels, purchases of spares and provisioning for new program starts. In this sense, the DMDS fulfills a vital role and should be fully integrated at NARF Alameda. More important to the purpose of this report, however, are the management reports generated by the DMD System. As stated, the most immediately useful cost information for NARF managers is trend and special information. The ability of DMDS to provide precisely these types of information will be discussed next. Rather than list every report available

from the system, the following discussions select a few and present ideas about their use.

The first DMDS report that provides important management information is the SDLM AIRCRAFT SUMMARY DATA REPORT. It shows, by Aircraft Bureau Number, induction dates, completion dates, number of working days and number of man-hours. The format of the report is excellent and will easily accommodate analysis of general and specific trends on any or all of the above areas of concern.

Another report that is ideally suited to management needs is the NARF JOB ORDER NUMBER REPORT. It provides direct civilian labor cost, direct material cost, indirect general and administrative cost, and indirect production cost information by job order number and by aircraft bureau number. This report facilitates the analysis of specific trends and will provide some specific or special information.

The UNSCHEDULED REPAIR ACTIONS REPORT shows, by bureau number, the five aircraft requiring the largest number of unscheduled maintenance actions. This report would facilitate the examination of special situations such as the occurrence of stabilizer attach fitting cracks on inducted aircraft. A closely related report, that shows the man-hours expended on unscheduled maintenance actions, would

prove extremely useful in the preparation of a well documented budget argument.

The DMD System provides other reports that present information in many areas, but this brief discussion is sufficient to make the point that DMDS is superior to the NIF system in providing management information. DMDS, in short, is the best means of providing required management information at least cost in terms of organizational resources. Much of the groundwork for its implementation has already been done at NARF Alameda. The transactors are in place. The software has been written and debugged. The system's use is mandated by higher authority. All that is required is management support, and such support would yield great dividends.

III. S-3 OPERATIONAL SERVICE PERIOD LENGTH CONSIDERATIONS

As a significant contributor to Life Cycle Cost, SDLM has been the object of close scrutiny within the S-3 program. Attention from external sources has forced a close look at rework costs and the devotion of intensified effort toward their management. Information that facilitates the intensification of cost management effort was the thrust of the previous chapter. The object of this chapter is to present a straightforward look at OSP issues by first reviewing the changes that have occurred in maintenance concepts since 1970, and then examining the evolution of the Reliability Centered Maintenance (RCM) Program. Finally, brief applications of RCM logic are related to S-3 OSP issues in an effort to provide management insight for these concerns.

Naval aviation maintenance philosophy has changed significantly over the life of S-3 aircraft. All are familiar with the Naval Aviation Maintenance Program (NAMP) as delineated in OPNAV Instruction 4790.2 (series), where the three level maintenance concept is defined. This familiarity may lead into a subtle trap, however. The idea of dividing the life of an airplane up into operating segments that are separated by maintenance segments during

which total aircraft rework is performed, is a comfortable one. Completely rebuilding or reworking an airframe periodically makes intuitive sense. The subtle trap mentioned lies precisely in this confidence. Research indicates that some managers have been lulled into a willingness to defend what it seems the OSP ought to be, rather than embrace new and possibly better ideas. A recent unsupported proposal to shorten the S-3 OSP was turned down by NALC where a documented proposal that embraced current thought and procedure might not have been. Specifically, the NALC response stated, in part, that [Ref. 8:p. 11] "Specific information, supported by RCM analysis, is considered essential to ensure that the (proposed) OSP is technically valid and could sustain a rational challenge." This point is crucial. Other echelons of command require that OSP proposals possess the attributes of technical validity and rational soundness. The officially recognized source for these attributes is the analysis/logic framework within the RCM program. Proposals can no longer be based upon what seems right, and preconceived ideas about SDLM frequency, depth and breadth must be dropped. This does not mean that common sense cannot be exercised, but no longer can appeals with little or no technical substance be expected to decide OSP length issues that involve such high monetary stakes. Both RCM analysis and the formalized

collection of data to facilitate that analysis must become integral to the rework process at NARF Alameda.

What evolutionary changes in maintenance philosophy led to RCM? The following background is found in the RCM Handbook [Ref. 8:p. iii]:

"Early approaches to preventive maintenance programs were based on the concept that periodic overhaul ensures reliability and therefore operating safety. Tests by the airlines in 1965 showed that scheduled overhaul of complex equipment has little or no effect on the reliability of the equipment in service. These tests identified the need for a new concept for preventive maintenance, which was eventually developed in 1968."

Preventive maintenance programs that did not assume a relationship between periodic rework, reliability and safety were named Reliability Centered Maintenance programs, and were first implemented by the airlines in 1970. The first applications of these techniques by the U.S. Navy were made in 1972 in the S-3A, P-3A, and F-4J programs. Dropping the assumption that reliability and safety depend upon rework is not all that identifies RCM programs, however. Even broader in focus, they are intended to ". . . provide the organizational focus and systematic procedures to (1) analyze the maintenance requirements for . . . aircraft, (2) objectively justify every maintenance requirement, and (3) enforce the performance of only the justified maintenance actions." [Ref. 9: p. 11] RCM implementation is mandated in Defense Guidance through the Chief of Naval

Operations. Further background is provided in a study performed by the Center for Naval Analyses which is appended to this report. [Ref. 10]

While early applications of RCM techniques to the S-3 program seem to have resulted in an airplane that exhibits unanticipated failure modes, follow-on applications of the techniques are through the Age Exploration Program (closely related to RCM), are designed to accommodate these unanticipated failures. These follow-on applications depend upon the formal accumulation and examination of failure data resulting from S-3 operations and will not necessarily allow one to assume that those failures need to be corrected at the depot level.

An examination of the RCM program simply reveals logical formalizations of the thought processes that have always been used when deciding upon what and how much maintenance to do. The application of logic leaves no room for unsupported claims, however, and RCM is very different from old methods in that sense. The RCM analysis process consists of three higher order questions and a series of lower order questions incorporated into a logic tree that determines the type of maintenance task to be performed and the maintenance level at which it is to be performed. These determinations are made for both preventive and corrective maintenance actions. The higher order questions determine

the consequence of failure and the objective of the maintenance task based upon that consequence. In a situation where the consequence of failure is loss of an aircraft, for example, the objective of the RCM maintenance task is to prevent any failures from occurring. The lower order questions then translate the objective into a specific type of maintenance task that will accomplish the objective at least cost. With these essentials of the RCM system in mind, one can move to a brief look at the S-3 OSP length history, so as to set the stage for the examination of the OSP issues that formed the basis for NARF concern.

In 1973, after completion of initial contractor maintenance engineering analyses, the length of the S-3 operating service period was set at twenty-four months. OSP length was increased to forty-eight months (with a flight hour limit of 2200 hours) in 1975 after a joint Analytical Maintenance Program (AMP) study was completed by NARF Alameda/Lockheed. This study recognized the excellent material condition exhibited by airplanes that had been inducted after completing their initial twenty-four months of service. OSP length was increased again in 1980 to seventy-two months at the recommendation of NARF Alameda, after it was realized that fatigue life expenditure was less than expected. OSP length is presently at the seventy-two month level. Since 1980, Naval Air Systems Command has

considered increasing OSP length to ninety-six months, but has not yet decided to do so. Also since 1980, the Aircraft Service Period Adjustment (ASPA) program has been implemented, making OSP extensions for operating aircraft highly probable. This means that it is likely for some S-3 aircraft to go eighty-four months (one operating period of seventy-two months plus one twelve month extension) or more before induction. For these reasons and because of mounting concern over deteriorating aircraft material condition and new modes of material failure, NARF proposed shortening S-3 OSP length to forty-eight months in 1984. This proposal was refused for reasons discussed in following sections.

Official guidelines for the determination of OSP length are set forth in Appendix C of MIL-STD-2173(AS). In brief, this standard requires that OSP length be determined by establishing preventive maintenance requirements and intervals that prevent unacceptable aircraft degradation, and then determining which maintenance levels must perform those requirements. Those depot level requirements which have safety impacts are considered to be the primary factors affecting OSP, and they are grouped together so as to be performed at the end of specified operating intervals. Two other key concepts presented by the appendix are [Ref. 9: App. C, pp. 148-149]:

- The OSP is determined solely by justifiable scheduled depot maintenance requirements.
- The OSP analysis should not . . . reflect any preconception that aircraft must visit a depot facility on a scheduled basis, or that all scheduled depot maintenance must be done concurrently. The analysis to determine optimum OSP . . . must substantiate that required material condition will be achieved at least cost.

The logic tree presented in Figure 3 is taken from Appendix C of MIL-STD-2173(AS), and embodies the questions which must be asked of any maintenance task under consideration as an OSP determinant. It assumes that the task has already been evaluated through RCM analysis. This assumption holds true for both this report and the NARF proposal to shorten the S-3 OSP, the NARF OSP.

The four areas of concern contained in the NARF request are:

- (A) Unanticipated degradation and failure of flight control hardware (bearings, rod ends, fairleads, etc.).
- (B) Cracks in nonstructurally significant airframe components including sonobuoy deck, keelson longeron fitting and horizontal stabilizer attach fittings.
- (C) Significantly increased corrosion degradation and paint/sealant system failure since late 1982.
- (D) Requirement for depot replacement of canopy jettison pyrotechnic material at forty-eight month intervals.

Beginning with the flight control hardware failure issue, one must first determine (according to the question one in Figure 3), whether the flight control hardware

inspection/replacement task is an OSP candidate task. In order to be so classified, this task must either, (a) be associated with structural elements whose failures would result in a direct adverse effect on operating safety, or (b) result in significant economic consequences if not accomplished. The task does not meet the first condition, since a NARF Alameda letter of 1984 states that "The structurally significant item (SSI) inspections at SDLM have not indicated any major problem areas." [Ref. 11:p. 1] The question of significant economic consequences is not so easily answered, however. Such consequences probably exist, but so little has formally been done to document them that making a case will be extremely difficult. The first and most basic step is to consolidate every bit of data that exists on these failures into a data base upon which analysis can be performed. In order to justify the failures as OSP determinants, examination of this data will likely have to take the form of a Failure Modes and Effects Analysis (FMEA). This analysis would determine the types of failure being experienced and the operational effects (in terms of readiness), of each type of failure. Once failure effects are organized in this fashion, meaningful economic cost-tradeoff analysis is possible, contrasting cost of downtime due to failures with the cost of shortening the OSP (thereby increasing SDLM costs).

It seems that the second, third and fourth questions from Figure 3 concerning task performance, effectiveness and the need for depot skills and equipment, can be grouped together. In response to the second question, task effectiveness should be fairly easily shown once the operational (and attendant economic) consequences had been catalogued in response to the first question. In other words, the effectiveness of replacing worn hardware seems apparent, as it would eliminate the operational, and therefore the economic, consequence. The real question is whether depot skills and equipment are required to perform the task. In order to answer, one must look at the repair actions required to correct failure modes discovered in the FMEA. Unless the bulk of the maintenance tasks required depot skills and/or equipment, this question will result in rejection of the task as an OSP determinant, as Figure 3 shows. Suppose, for instance, that most of the maintenance involved in the task can be performed by squadron and intermediate maintenance personnel with only a limited requirement for depot work. Question five of Figure 3 then implies that aircraft modification would be considered before the task would be accepted as an OSP determinant. An example of this situation would be the assembly and distribution of "O" and "I" level airframes changes (AFC) kits for incorporation by fleet personnel. Any depot

OSP LOGIC DIAGRAM

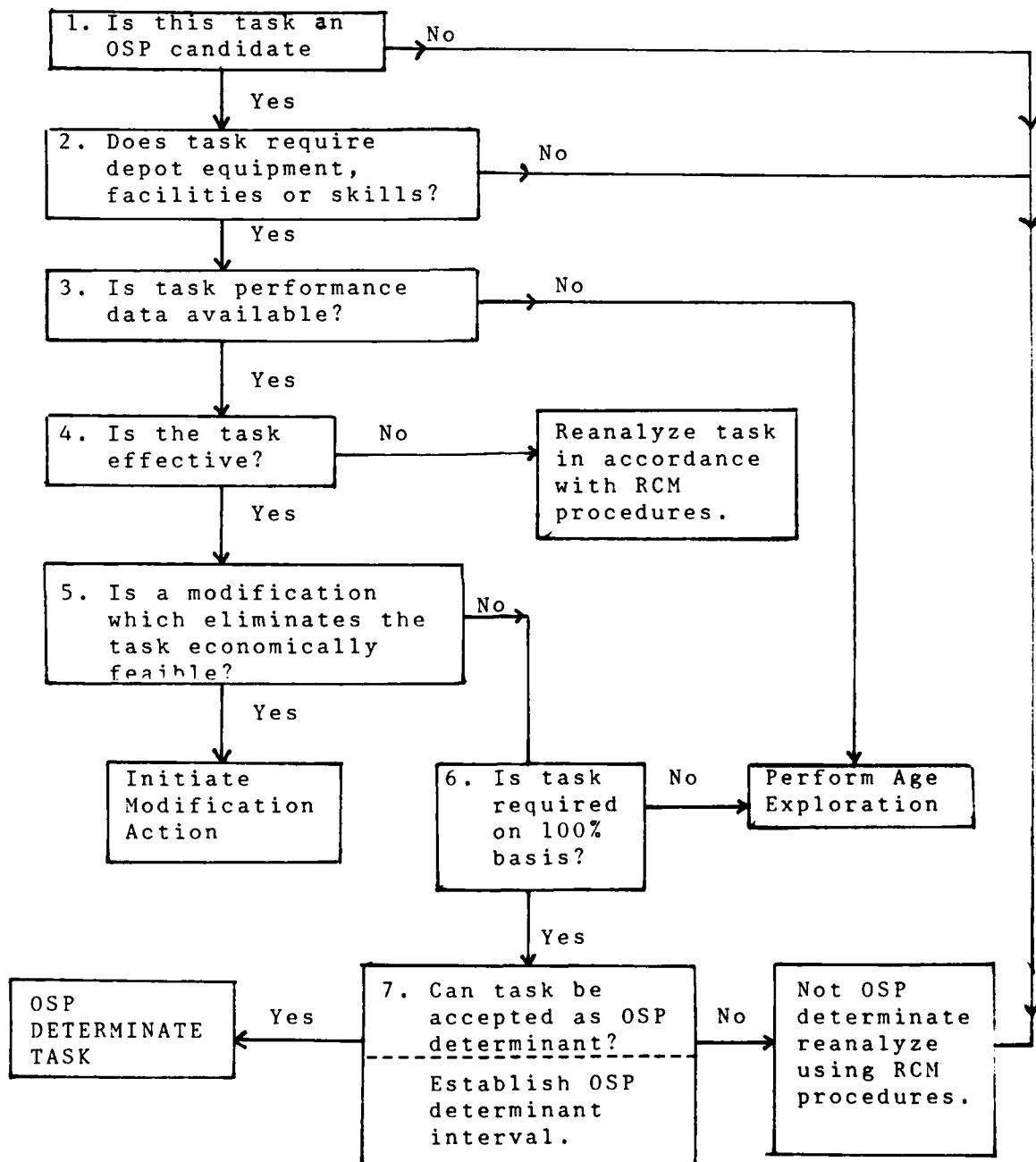


Figure 3 OSP Logic DIAGRAM

portions of the task would be performed on a scheduled basis by NARF field teams or as depot AFC's at SDLM. The practical upshot is that this task is very difficult to defend as an OSP determinant.

The second area of NARF concern involves cracks in various airframe components. As noted earlier, none of the components involved have yet been identified as SSI's. This makes defending an inspection/correction task as an OSP determinant nearly impossible on any grounds other than significant economic consequence. This is the reason that a review of the SSI List to determine whether any components affected by the cracks should be added is recommended in the following chapter. This review should be conducted in addition to a thorough FMEA. If none of the affected items can legitimately be added to the list, then defense of the inspect/correct tasks as OSP determinants becomes as difficult as the flight control hardware case, since both depend on making a sound case for significant economic consequence. Again, this case will rest upon the conduct of cost tradeoff analyses after requisite data has been collected and FMEA has been completed.

The third issue in the NARF OSP proposal concerned increased corrosion degradation and paint/sealant-system failure since late 1982. Once again the first question from Figure 3 requires showing that significant economic

consequences will result if the inspection/treatment/repaint task is not performed, since no safety structural components are involved. Showing that these consequences exist is difficult for two reasons. First, paint/sealant-system failure will have to be precisely defined. Hard standards must be formulated since the object will be to demonstrate the economy of performing corrosion treatment/repaint at the depot level every forty-eight months vice every seventy-two. This cost tradeoff analysis will depend on the percentage of aircraft which fail an inspection, and will not stand on a hazy or ill-defined standard. Second, the question of depot skill and equipment requirements presents a formidable difficulty in defending the task as an OSP determinant. Total repaint of an aircraft is a depot maintenance task, and essentially all other corrosion work within the Navy is defined as organizational level maintenance. Answering "yes" to the depot facilities and skills question then requires that aircraft which fail to pass the inspection standard need either total repaint or some other corrosion maintenance that fleet technicians cannot perform (such as treatment of major intergranular corrosion on an SSI). Anything less and the task cannot be justified as an OSP determinant. Probably a more viable alternative than defending this as an OSP task would be to propose intensified "O" level corrosion requirements through manual

changes (including maintenance frequency and depth), and to institute a more aggressive NARF Field Team effort to respond to those cases where damage requiring depot skills and facilities does exist. NARF funding constraints are obviously important here.

The final OSP issue brought to light in the NARF proposal is the requirement for depot removal and replacement of canopy-jettison pyrotechnic material at forty-eight month intervals. Of all the issues considered, this one appears to have the most merit. Failure of the canopy-jettison system due to nonperformance of the replacement task would certainly impact negatively upon operational safety. Therefore, the answer to the first question is yes. The answer to the second question is an automatic yes, since the task is defined as depot level maintenance. Analysis can stop at this point since this definition as a depot level task means that all subsequent questions can be answered in the affirmative. The task is by definition a legitimate OSP determinant in the Figure 3 sense. When the S-3 OSP was set at the original twenty-four month length, the pyrotechnic replacement task was required during the second SDLM visit and every other visit thereafter. At the forty-eight month OSP length, the task was required during every SDLM visit. With the present OSP length of seventy-two months, however, the task will only

become due coincident with SDLM at every third SDLM visit, leaving much work up to Depot Field Team repair. A change in either the OSP length or the interval at which this task is required seems economically sound. Since the other tasks examined here can be defended as OSP determinants only after extensive analysis has been performed (with the possible exception of those cases in which cracks can be shown to involve SSI's--see above), making a case for shortening the OSP on the basis of the pyrotechnic task alone will be difficult. Therefore, the recommendation of this report is that the present situation continue until some of the other analyses are completed.

The above examinations, though superficial, are intended for illustration rather than as the basis for OSP determinations themselves. It is realized that real-world FMEA and SSI List reviews require engineering talent to carry out. The intent here is to provide a perspective from which to move into discussions about related areas of interest concerning the S-3 OSP.

The first and most important point is the resounding need to centralize the data already gathered about above failure modes and to formalize methods of gathering this data. Centralization and formalization as a data base will enable managers to examine the data, eliminate any noise or duplication, and get down to the real business of Failure

Modes and Effects Analyses. Just as important, areas where data depth and breadth are presently insufficient to support such analyses will become apparent, and additional data can be sought.

More needs to be said about gathering critical information. The first chapter showed that a system for providing management cost information at NARF Alameda was needed. While a system for gathering data about significant aircraft failures does exist, it does not seem geared to provide data in a format that facilitates the construction of OSP proposals. Explicit procedures should be adopted that seek failure data upon aircraft induction. The system should be formalized and put under the cognizance of a manager or department that has, as a primary concern, the collection and interpretation of this data. Focus is crucial if tight defensible proposals are to be made.

A related area for which managerial focus and emphasis are absolutely important is the RCM area itself. This program must be given the highest possible priority since it is the foundation upon which the NARF maintenance effort rests. Higher command echelons view RCM analysis as the major determinant for SDLM content. Organizational structure should therefore be oriented toward ensuring that this analysis is made a routine and integral part of preparing OSP proposals.

Finally, OSP proposals must possess both technical validity and the ability to withstand rational challenge in order to succeed. Technical validity is assured when thorough data collection and extensive FMEA are completed. This "technical homework" is precisely the type of work NARF Alameda, as Cognizant Field Activity (CFA) for the S-3, is expected to perform. Indeed, as the CFA and recognized source of expertise for that weapon system, NARF Alameda should rarely be challenged when it has rendered a technical judgement based upon its research and engineering. The second requirement--"the ability to withstand rational challenge"--is a more difficult one to meet. The ability to withstand such challenges evidently requires the performance of global cost-tradeoff analyses which show clearly that S-3 LCC will be significantly reduced by the proposed action. It does not seem that a NARF is appropriately suited for such analytical work, nor should OSP proposals be denied simply because they do not leave NARF with these analyses attached. If NARF research and expertise show that a proposal for an OSP change has technical merit, then cost tradeoff analysis to determine whether the proposal has economic merit seems a job for other experts. At least, in such cases, funding should be provided so that NARF can contract for the requisite cost analyst expertise when required.

This completes the examination of OSP issues. The following chapter serves to consolidate and present conclusions and recommendations with regard to both this chapter and the previous one.

IV. CONCLUSIONS AND RECOMMENDATIONS

This chapter presents conclusions drawn from this report and makes recommendations based upon those conclusions. The first section deals with the cost area and the second takes up the OSP area. Each section begins with general remarks, which are followed by itemized suggestions for action.

A. COST INFORMATION

NARF Alameda has a cost data-gathering system in operation which is designed to meet the data requirements of the NIF Accounting System, but which fails to provide good cost management information. Because of its narrow focus, the system provides data that is neither current, necessarily relevant nor properly formatted. Special information needs (e.g., trends or tracing costs to specific bureau numbers) often require significant hand manipulation, if indeed the information can be retrieved from the system at all.

Managers at various levels need rework cost information in the forms of general trend, specific trend and special case information. Such information is required both for internal cost and rework program management, and for externally defending budget requests or framing proposals to

change SDLM frequency, depth or breadth. Recommendations therefore are that NARF:

- Implement the Depot Maintenance Data System as soon as possible. This system is mandated by higher authority. Software programming and system design problems have been solved. Benefit will be realized immediately, since many information needs will be met by this system alone. Successful implementation will depend directly upon the amount of support the system receives. Therefore, implementation responsibilities should be specific.
- Examine the exact nature of the cost information needs of managers. Inputs should be sought from all relevant managers. These inputs should be scrubbed and prioritized to ensure that resources expended to design and implement any information system provide maximum benefit. Again, specific managers or departments should be assigned implementation responsibilities as appropriate.
- Compare information needs to the information provided by the NIF Accounting System and the DMD System. Determine, using contracting if necessary, whether minor procedural or system changes would meet any remaining information needs.
- For information needs which can be met by neither the NIF System nor DMDS, consider contracting for additional data base management system capability that would allow various avenues of data access and random management query. Economic justification for such a complex and expensive system admittedly depends on the importance of making the information available to managers.
- Become more aggressive in the use of cost information in framing and defending proposals to other echelons of command. Make SDLM cost impacts, even if they are only "best estimates," a part of OSP change proposals.

B. S-3 OSP LENGTH CONSIDERATIONS

Fleet activities that are receiving reworked S-3 aircraft from NARF Alameda are satisfied with those

aircraft. All fleet maintenance officers interviewed for this report expressed this satisfaction with regards to airworthiness, safety and material condition (NOTE: In fact, the ONLY areas that garnered any negative comment were specific problems with individual component rework and the Customer Service program--both minor/isolated and neither of concern here). NARF Alameda's S-3 rework program is "getting the job done" in terms of safety and quality. There is a problem, however, that seems to center around the apparent degradation of the CFA role for the S-3 aircraft. NARF Alameda can strengthen its role as CFA through consistent preparation of unreputably thorough, economically and technically sound proposals. These proposals should leave no question about who are the technical and engineering experts for the S-3 aircraft. This role should be a source of strength to demonstrate the talent and expertise employed at NARF Alameda. Recommendations therefore are that NARF:

- Aggressively exercise engineering judgement and make this judgement known to other echelons of command. As noted in chapter three, technical judgements rendered by NARF that are based upon engineering expertise can hardly be doubted. If the S-3 OSP issues NARF raised are truly important, then they deserve thorough technical investigation/documentation and the best effort possible in supporting them at the next level of command. These efforts must embrace RCM analysis. A change of "mind-set" may be called for in the above areas.

- Embrace the techniques of RCM analysis and Age Exploration. Full support for these programs is, quite simply, assumed by higher echelons of command. Lack of RCM/Age Exploration analysis guarantees failure for OSP and related proposals. Assign responsibility for the program to appropriate personnel/departments, under a separate branch if necessary. Ensure that all reports of new failure modes, or new data on known modes, is routed through the RCM branch. Devote whatever organizational resources are required to these efforts, since they determine SDLM content in a very real sense.
- Consolidate and formalize failure and discrepancy data that relates to OSP issues and SDLM content. Consider a data base concept to ensure that both fleet inputs and inputs that originate from inducted airplanes are routed promptly to the RCM Analysis Branch for examination. Ensure that these failure/discrepancy inputs are catalogued in a formal "repository" which allows quick recall and ease of manipulation. Such a system may be manual. The important thing should be that the system be formalized, and explicit enough to ensure proper routing and handling of data.
- Begin performing explicit Failure Modes and Effects Analyses on failure/discrepancy data. This effort will be facilitated by the consolidation and formalization described above. These analyses must be as rigorous and technically sound as data limitations allow. Additional data should be sought, where needed, through Airframes Bulletins (one-time inspections for the existence of a condition or failure) and other means as appropriate. In conjunction with this effort, review the SSI List for currency in view of new airframe modes, to determine whether items affected by new cracks should be added.
- Provide other echelons of command with estimated cost impacts (at least as far as SDLM is concerned) when proposals are made to change SDLM frequency, breadth and depth.
- Request clarification from NALC about the responsibility for Life Cycle Cost tradeoff analyses required by RCM procedures. It is not felt that these analyses should be the responsibility of a NARF, as stated earlier.

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